Technical Report No. 7
Contract N6onr-07129
NR 017-412

Physics of the Solid State
University of Illinois
Urbana, Illinois
Department of Physics

Principal Investigator
Robert J. Maurer

June 1953

U. S. Department of the Navy
Office of Naval Research
Washington, D. C.

ELECTRONIC HALL EFFECT IN NaCl

Alfred G. Redfield
U. S. Atomic Energy Commission predoctoral Fellow
University of Illinois

By applying the pulsed light method of Pohl and his co-workers[1] to the measurement of electronic Hall effect in insulating photoconductors it has been possible to avoid the space charge difficulties present in previous work[2,3]. The electrode arrangement is shown in Figure 1. The battery V_L sets up a potential gradient on the lower surface of the crystal, and thus an inhomogenious field in the crystal which is, on the average, in the x-direction. The upper plate is held at ground potential by the electrometer circuit; the potential of the entire lower plate can be changed with the potentiometer, and moving the potentiometer tap rotates the electric field in the crystal. The electrometer responds only to the component of charge flow which is in the y direction.

In making a measurement, a magnetic field is applied in the z direction, the crystal is illuminated with pulses of light a few seconds in duration, and the potentiometer is adjusted until the electrometer gives zero deflection during illumination. This means that the average charge flow in the crystal is in the x direction parallel to the electrodes, but the average electric field is at an angle, the Hall angle, to the electrodes. To eliminate space charge, the batteries are turned off between each observation of the electrometer and the crystal is illuminated with a strong light.

The magnetic field is then reversed and the potentiometer is again adjusted as before, so that the average charge flow is again in the x direction but the average electric field has been rotated through twice the Hall angle. Using a theorem of Shockley[4] it can then be shown rigorously that (for small θ)

$$\frac{2\mu H}{c} = 2\theta = \frac{\Delta V}{D} \frac{\int n\tau dv}{\int E_x n\tau dv}$$

where μ is the mobility, H the magnetic field, c the velocity of light, θ the Hall angle, D the thickness of the crystal, n the number of electrons per unit volume released by the light, τ the mean electronic lifetime, and E_x the x component of electric field in the crystal. The integrations are over the volume of the crystal.

This method differs from the conventional one in several ways. First, it is a transient method. Second, the electric field inside the crystal is rotated by external electrodes, rather than by the electrons under study. Finally, no attempt is made to inject or eject electrons through the surface of the crystal. The method cannot be applied directly to crystals having finite dark conductivity. It has already been applied to diamond.[5]

Both additively colored and x-rayed Harshaw NaCl crystals have been studied and the charge released from F centers in these crystals gives a Hall voltage polarity characteristic of electrons. At 82 $\pm$ 2°K the mobility is 250 $\pm$ 50 cm^2/volt sec., and at 200°K the mobility is of the order of forty. The experimental error is due to noise in the conducting plates, F center bleaching, temperature variations, or possibly crystal imperfections. By violently quenching the crystal its mobility can be reduced to as low as 150 cm^2/volt sec. at 82°K. These observations are in reasonable agreement with both the theory of Frohlich and Mott[6] and the more recent calculation of Low and Pines[7]. Work is under way to improve and extend these measurements.

The help of many people in this work is gratefully acknowledged; the author wishes particularly to thank Dr. R. J.

Maurer for his frequent suggestions and Dr. C. P. Slichter and his associatod for the use of their magnct.

References

1. R. W. Pohl, Proc. Phys. Soc. (London) 49 (Extra part), 3 (1937).
2. J. Evans, Phys. Rev. 57, 47 (1940).
3. C. C. Klick and R. J. Maurer, Phys. Rev. 81, 124 (1951).
4. W. Shockley, J. Appl. Phys. 9, 635 (1938).
5. A. Redfield, paper presented at the 1953 North Carolina meeting of the American Physical Society.
6. Frohlich, Pelzer, and Zienau, Phil. Mag. 41, 221 (1950).
7. F. E. Low and D. Pines, letter to be published in the Physical Review.

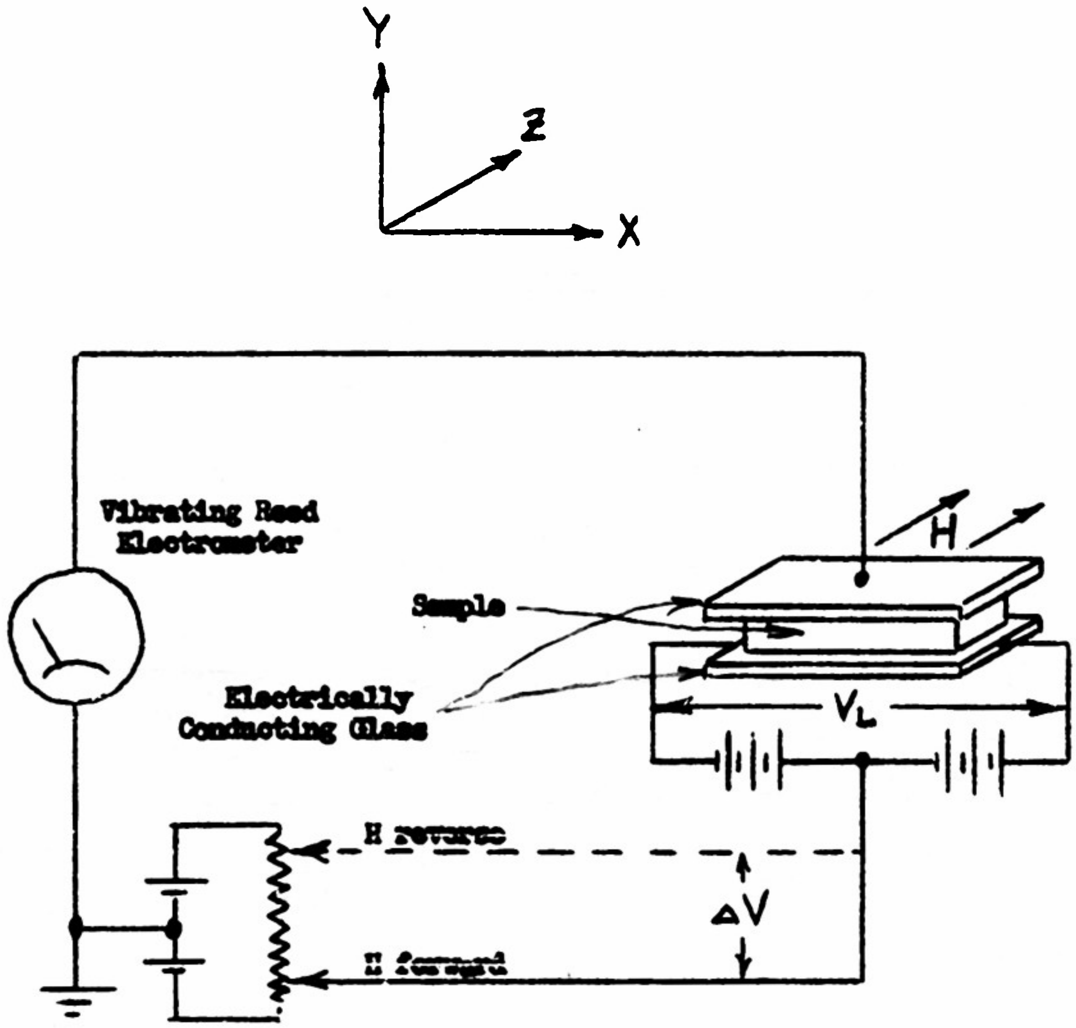

Figure 1. Electrode arrangement for observing electronic Hall effect in insulating photoconductors.